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This document summarizes the results of streamlined, risk-based corrective action (RBCA) assessments performed at nine Air Force sites with fuel-contaminated groundwater. The goal of this risk-based remediation approach was to find the most cost-effective method of reducing current and future potential risk by combining chemical source reduction, chemical migration control, and receptor restriction risk-reduction techniques.

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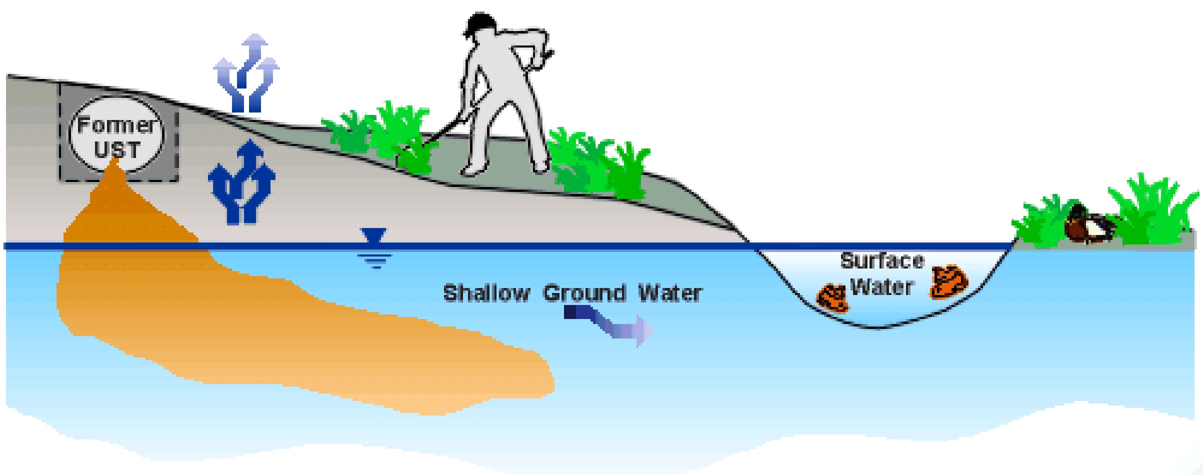
# Streamlined Risk-Based Closure of Petroleum Contaminated Sites Performance and Cost Results From Multiple Air Force Demonstration Sites

## Technology Demonstration Summary Report




October 1999

Air Force Center for Environmental Excellence

# STREAMLINED RISK-BASED CLOSURE OF PETROLEUM CONTAMINATED SITES
# PERFORMANCE AND COST RESULTS FROM MULTIPLE AIR FORCE DEMONSTRATION SITES

## TECHNOLOGY DEMONSTRATION SUMMARY REPORT

**October 1999**

**Prepared For**

**Air Force Center for Environmental Excellence**
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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AETC | Air Education and Training Commend |
| AFB | Air Force base |
| AFCEE/ERT | Air Force Center for Environmental Excellence/Technology Transfer Division |
| ASTM | American Society for Testing and Materials |
| AVGAS | aviation gasoline |
| BTEX | benzene, toluene, ethylbenzene, and xylenes |
| bgs | below ground surface |
| BX | base exchange |
| CAP | corrective action plan |
| COC | chemical of concern |
| COPC | chemical of potential concern |
| DDC | density-driven convection |
| DEHNR | Department of Health and Natural Resources |
| FFS | focused feasibility study |
| IEUBK | Integrated Exposure Update Biokinetic (model) |
| LTM | long-term monitoring |
| MDEQ | Mississippi Department of Environmental Quality |
| µg/kg | micrograms per kilogram |
| µg/L | micrograms per liter |
| mg/kg | milligrams per kilogram |
| MNA | monitored natural attenuation |
| NA | not analyzed |
| NFA | no further action |
| NIOSH | National Institute of Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |
| PAH | polynuclear aromatic hydrocarbon |
| PEL | permissible exposure limit |
| RAP | remedial action plan |
| RBCA | risk-based corrective action |
| RBSL | risk-based screening level |
| SSTL | site-specific target level |
| SVE | soil vapor extraction |
| TCL | target cleanup |
| TLV | threshold limit values |
| TNRCC | Texas Natural Resource Conservation Commission |
| TPH | total petroleum hydrocarbons |
| USEPA | US Environmental Protection Agency |
| UST | underground storage tank |

# SECTION 1

# PROJECT OVERVIEW

This document summarizes the results of streamlined risk-based corrective action (RBCA) assessments performed for nine US Air Force sites with fuel-contaminated groundwater. The project was performed for the Air Force Center for Environmental Excellence, Technology Transfer Division (AFCEE/ERT) under Air Education and Training Command (AETC) Contract No. F41689-96-D-0710, Order No. 5015. Details of the site-specific assessments are available in the individual corrective action plans.

## 1.1 SUMMARY OF THE RISK-BASED APPROACH

The objective of risk-based remediation is to reduce the risk of specific chemicals to human health and/or ecological receptors (i.e., nondomesticated plants and animals). For any chemical to pose a risk, four elements must exist at the site:

- A source of chemical contamination that exceeds or could generate chemical contamination above health-protective or aesthetic standards;
- A mechanism of contaminant release;
- A human or ecological receptor available for chemical contact; and
- A completed exposure route through which that receptor will contact the chemical.

If any one of these four elements is absent at a site, there is no current risk. The reduction or elimination of risk can be accomplished by limiting or removing any one of these four elements from the site.

The goal of this risk-based remediation approach was to find the most cost-effective method of reducing current and future potential risk by combining three risk-reduction techniques:

- Chemical source reduction - Achieved by natural attenuation processes over time or by engineered removals such as free product recovery, soil vapor extraction (SVE), or *in situ* bioventing.
- Chemical migration control - Examples include natural attenuation of a groundwater plume, and SVE to prevent migration of hazardous vapors to a receptor exposure point.
- Receptor restriction - Examples include land use controls and site fencing to control receptor exposure to site contaminants until natural attenuation and/or engineered remediation reduce the chemical source and/or eliminate the potential for chemical migration to an exposure point.

This project involved RBCA evaluations at nine sites in four states at which groundwater is contaminated with petroleum hydrocarbons. At all sites, benzene, toluene, ethylbenzene, and/or xylenes (BTEX) were primary chemicals of potential concern (COPCs).

## 1.2 PROJECT TASKS

The major tasks of this risk-based project were:

- Assessing available data and collecting any supplemental site characterization data necessary to define the nature, magnitude, and extent of soil and groundwater contamination and to document to what degree natural attenuation processes are affecting contaminant concentrations;
- Determining if an unacceptable risk to human health or the environment currently exists or may exist in the foreseeable future using future lands use plans, applicable regulatory guidance, contaminant fate and transport predictions, and exposure concentration estimates;
- Evaluating and recommending a remedial alternative that both reduces the source of contamination and minimizes or eliminates risks to potential receptors; and
- Documenting the remedial action selection process in a corrective action plan (CAP) that satisfies regulatory requirements.
- Whenever possible, obtaining site closure approval or approval of a site closure plan.

A primary objective of the project was to streamline and economize the implementation of the Air Force Natural Attenuation Protocol (AFCEE, 1995), thereby demonstrating the feasibility of using this approach at commercial/industrial (i.e., non-government) sites. The project was performed during the period from July 1997 to September 1999.

## 1.3 TEST SITE LOCATIONS AND SITE DESCRIPTIONS

The nine sites evaluated during this project are summarized in Table 1.1 and their locations are shown on Figure 1.1. All are sites at which petroleum hydrocarbon releases have resulted in groundwater contamination. Seven of the sites had a single, dissolved-contaminant plume emanating from a single source area. The remaining two sites (Randolph Air Force Base [AFB] and Tyndall AFB Base Exchange [BX] Service Station) each had two distinct source areas and contaminant plumes. In most cases, the specific contaminant release dates are not known. However, most of the releases occurred prior to 1992.

Engineered remedial actions, focusing primarily on source reduction, had been implemented at six of the nine sites prior to the performance of this project. Source reduction techniques included bioventing, SVE, soil excavation, and in-well density-driven-convection (DDC) aeration. In addition, a groundwater pump-and-treat system was operating to control plume migration at the Eglin AFB Seventh Street Service Station, and a single air sparging well was operating at the Eglin AFB Military Gas Station to reduce dissolved BTEX concentrations.

**TABLE 1.1**
**PROJECT SITES**

| Site ID | Location | Contaminant Source | Release Date |
|---|---|---|---|
| Seventh Street Service Station | Eglin AFB, Florida | Leaking gasoline underground storage tanks (USTs) and associated piping | Prior to 1983 |
| Military Gas Station | Eglin AFB, Florida | Leaking gasoline USTs and associated piping | Prior to 1991 |
| BX Service Station, Area of Concern-A (ST-06) | Keesler AFB, Mississippi | Leaking gasoline USTs and associated piping | Prior to 1987 |
| Building 4522 | Seymour Johnson AFB, North Carolina | JP-8 aviation fuel leak in a valve pit | December 1995 |
| Site ST-08 (Building 41105) | Pope AFB, North Carolina | Leaking #2 fuel oil USTs | Prior to 1992 |
| Former Building 2093 Gas Station | Kelly AFB, Texas | Leaking gasoline USTs and associated piping | Prior to 1989 |
| Base Exchange Service Station (Site ST019) | Randolph AFB, Texas | Leaking gasoline USTs and associated piping; release from an aviation gasoline (AVGAS) transmission pipeline | Prior to 1987 (fuel UST plume) 1996 (AVGAS pipeline plume) |
| Base Exchange Service Station | Tyndall AFB, Florida | Leaking gasoline USTs and associated piping | Prior to 1984 (former UST area)<br>Prior to 1987 (current UST area) |
| Site FT-16 | Tyndall AFB, Florida | Fire training activities | Prior to 1980 |

Figure 1.1. Air Force Streamlined Risk-Based Site Closure Initiative Locations


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## 1.4 REGULATORY REQUIREMENTS

The nine project sites were located in four states: Florida, Mississippi, North Carolina, and Texas. Each of the four states in which the project sites are located have developed RBCA regulations or guidance for petroleum underground storage tank (UST) sites. The site-specific approaches were designed to comply with the state RBCA programs. The RBCA programs for each of the four states are briefly summarized in the following subsections.

### 1.4.1 Florida

Guidance for determination of remedial requirements for closure of petroleum-contaminated sites, including several mechanisms for determining matrix-specific cleanup criteria, has been developed by the Florida Department of Environmental Protection (FDEP, 1997). The regulations allow closure of petroleum release sites under several different scenarios, including:

- No-Further-Action (NFA) Proposal Without Conditions,
- NFA Proposal With Conditions, or
- Monitoring-Only Proposal for Natural Attenuation.

A remedial action plan (RAP) must be prepared for sites that do not meet the requirements for NFA or monitored natural attenuation (MNA). Closure of a site under the NFA-Without-Conditions alternative would allow unrestricted future use of the site (i.e., residential land use), and therefore the requirements and allowable contaminant levels under this alternative are the most restrictive. The NFA-With-Conditions alternative requires that appropriate institutional or engineering controls be implemented to limit receptor exposure. Sites seeking closure under this alternative are subject to potentially less stringent cleanup levels. MNA is a recognized means of remediating a site, with the goal of achieving the NFA cleanup target levels. However, natural attenuation is considered to be an appropriate remedy only if the site is anticipated to achieve the applicable NFA criteria in five years or less.

Matrix-specific Target Cleanup Levels (TCLs) for petroleum constituents are provided in "look-up" tables or through reference to other applicable regulations (i.e., state groundwater or surface water regulations). Contaminant concentrations in all affected media at a site must be below all applicable TCLs in order for the site to qualify for an NFA (with or without conditions) proposal. However, the rule also allows for the development of alternative cleanup standards based on a site-specific risk assessment for use in a With-Conditions-NFA-Proposal. These site-specific alternative cleanup standards can be used in place of those presented in the look-up tables.

### 1.4.2 North Carolina

Guidance for determination of soil and groundwater remedial requirements for closure of petroleum-contaminated UST-related sites is available from the North Carolina Department of Environment, Health and Natural Resources (DEHNR, 1998a, 1998b, and 1998c). Sites are classified as high, intermediate, or low risk based on the threat to

potential receptors, the potential future use of groundwater, explosion or fire hazard, contaminant concentrations in groundwater, and the presence or absence of free product. The level of reporting and remediation required is commensurate with the risk level. **State guidance requires that MNA be considered as a remedial option and used to the maximum extent possible**. Multiple sets of Tier 1 RBSLs are provided based on the risk level and land use. For low-risk sites, site closure with NFA can be approved. The guidance does not explicitly allow for the development of alternative, site-specific cleanup levels.

### 1.4.3 Mississippi

The UST Division of the Mississippi Department of Environmental Quality (MDEQ), Office of Pollution Control mandates cleanup levels for BTEX and total petroleum hydrocarbons (TPH). However, other cleanup levels may be considered using a tiered approach with risk-based analysis and screening of COPCs. Two options are allowed under state regulations:

Tier 1: Using generic, risk-based screening levels (RBSLs) calculated by MDEQ (1996) and presented in "look-up" tables; or

Tier 2: Based on the completion of a limited risk assessment, using site-specific human health risks to develop site-specific cleanup levels in accordance with American Society for Testing and Materials (ASTM, 1995) Standard 1739 (RBCA guidance for petroleum release sites).

A tiered approach would employ the Tier 1 screening criteria to determine if current site conditions warrant further evaluation of potential human health risks through a Tier 2 assessment. If the screening process (Tier 1) or limited risk assessment (Tier 2) indicates that no contamination is present above the selected site action levels, then no type of remediation is warranted, and the site can proceed to closure.

### 1.4.4 Texas

Published guidance (Texas Natural Resource Conservation Commission [TNRCC], 1994, 1997a, and 1997b) contains information regarding the RBCA process and the establishment of remediation targets for sites regulated by the Petroleum Storage Tank Division of the TNRCC.

The two options for risk-based analysis and screening of COPCs are:

Plan A: Use specified methods, conservative assumptions regarding potential human exposure, and site-specific factors to calculate site cleanup levels (i.e., a "Tier 1" screening level); or

Plan B: Complete a limited risk assessment using site-specific human health and/or ecological risks to develop site-specific cleanup levels (i.e., a "Tier 2" screening level).

A tiered approach would use the Plan A screening criteria to determine if current site conditions may warrant further action, and to evaluate potential human health risks that can be more accurately quantified in a Plan B assessment. If the screening process (Plan

A) or limited risk assessment (Plan B) indicates that no contamination is present above the appropriate site action levels, then no remediation is warranted and the site can proceed to closure.

Streamlined site closure criteria are presented for sites where future exposure potential is low. Depending on site conditions (e.g., stability of the plume, site restrictions), closure of low priority sites may be obtained by completing a closure request form and implementing appropriate institutional controls (e.g., water use within the impacted aquifer near the site).

# SECTION 2

# PROJECT TASKS

## 2.1 KICKOFF MEETING

A project kickoff meeting was held for each Base to familiarize Base and regulatory personnel with the project scope and objectives, and to permit information gathering and a site visit. Several project tasks were accomplished for each site, as described in the following subsections.

## 2.2 WORK PLAN

Draft and final work plans were prepared for each site. The work plan summarized:

- Applicable state guidance and regulations governing RBCA activities;
- Site background information;
- Proposed site characterization activities; and
- Proposed data analysis, fate and transport modeling, and report preparation.

## 2.3 FIELD SITE CHARACTERIZATION

An average of 4 to 5 days of field work was performed at each site to define the current nature, extent, and magnitude of regulated contaminants, assess changes in contaminant concentrations over time, and evaluate the occurrence of natural attenuation. A Geoprobe® was used at seven of the nine sites to collect subsurface soil samples and install small-diameter (i.e., 0.5-inch) groundwater monitoring points. At the remaining two sites (Kelly and Randolph AFBs, Texas), the depth to groundwater and the presence of subsurface gravel and cobbles prevented the use of a Geoprobe®. Therefore, soil borings at Kelly AFB were advanced and monitoring wells were installed by the US Army Corps of Engineers using a truck-mounted auger rig. At Randolph AFB, the required drilling and well installation was performed by another base contractor that was performing a concurrent investigation at that site. Groundwater sampling was performed using AFCEE (1995) approved procedures described in AFCEE (1995). Field meters and test kits were used to the extent possible to measure the concentrations of geochemical parameters for the natural attenuation evaluation.

On average, the following site characterization activities were conducted at the site:

- Five soil borings were advanced, eight subsurface soil samples were collected for laboratory analysis of contaminants, and three soil samples were collected for total organic carbon (TOC) analysis (Table 2.1);

**TABLE 2.1**
**ANALYTICAL PROGRAM**

| Analyte [a] | Soil | Groundwater | Soil Gas | Field or Fixed-Base Analysis |
|---|---|---|---|---|
| Aromatic VOCs | X | X | X | fixed-base |
| PAHs | optional | optional | NA [b] | fixed-base |
| TPH | optional | optional | optional | fixed-base |
| Lead | optional | optional | NA | fixed-base |
| Dissolved Oxygen | NA | X | NA | field |
| Nitrate | NA | X | NA | fixed-base |
| Ferrous Iron | NA | X | NA | field |
| Sulfate | NA | X | NA | field |
| Sulfide | NA | optional | NA | field |
| Methane | NA | X | NA | fixed-base |
| Manganese | NA | optional | NA | field |
| Ammonia | NA | X | NA | field |
| Alkalinity | NA | X | NA | field |
| ORP | NA | X | NA | field |
| Temperature | NA | X | NA | field |
| Conductivity | NA | X | NA | field |
| pH | NA | X | NA | field |
| TOC | X | NA | NA | fixed-base |

[a] VOCs = volatile organic compounds, PAHs = polynuclear aromatic hydrocarbons, TPH = total petroleum hydrocarbons, ORP = oxidation reduction potential, TOC = total organic carbons.

[b] NA = not analyzed.

- Two groundwater monitoring points were installed and an average of nine groundwater samples were collected for field and laboratory analysis from existing wells and the new monitoring points (Table 2.1);

- Two subsurface soil gas samples were collected for laboratory analysis from an average depth of 3 feet below ground surface (bgs);

- Two aquifer slug tests were performed; and

- The elevations of the two new monitoring points were surveyed.

The samples were analyzed either by AFCEE-approved fixed-base laboratories or in the field. Target analytes included known site fuel contaminants, analytes required under the applicable state regulations and/or guidance, and a suite of geochemical parameters for the natural attenuation assessment.

## 2.4 CORRECTIVE ACTION PLAN

Draft and final CAPs were prepared for each site. The CAPs described:

- Site characterization activities;
- Physical characteristics of the study area;
- Tier 1 analysis and identification of COPCs;
- The extent and magnitude of COPCs in the environment;
- Chemical fate assessment performed using evidence of contaminant attenuation over time, evidence of contaminant biodegradation via microbially mediated reduction/oxidation reactions, and the analytical model BIOSCREEN (Newell *et al*., 1996);
- Tier 2 identification of final chemicals of concern (COCs);
- An optional focused feasibility study (FFS) consisting of development and evaluation of a maximum of three remedial alternatives in terms of effectiveness, implementability, and cost; and
- A long-term monitoring (LTM) plan for site groundwater.

An FFS was performed only if the chemical fate assessment indicated that natural attenuation alone would not achieve cleanup goals within 10 years.

## 2.5 FINAL MEETING

Final meetings were held for selected sites to brief regulators on the results and recommendations stemming from the RBCA study.

# SECTION 3

# PROJECT RESULTS

The results of the RBCA investigations at the nine Air Force sites are summarized in this section.

## 3.1 SITE CONTAMINATION SUMMARY

The areal extent of contamination (source area plus dissolved BTEX plume) at the sites ranged from 1.1 to 7 acres, and averaged 2.7 acres. The most common COPCs identified during Tier 1 screening included BTEX, naphthalene, and lead. Maximum BTEX and naphthalene concentrations in source area soils ranged from 0.01 milligrams per kilogram (mg/kg) to 2,193 mg/kg and 6.5 mg/kg to 46 mg/kg, respectively. Maximum dissolved BTEX, naphthalene, and lead concentrations in groundwater ranged from 133 micrograms per liter (µg/L) to 25,686 µg/L, 0.6 µg/L to 510 µg/L, and 0.008 µg/L to 62 µg/L, respectively.

## 3.2 TIER 1 SCREENING RESULTS

For each site, a Tier 1 screening was performed to compare maximum detected contaminant concentrations in sampled media to conservative, generic RBSLs that were typically available in State look-up tables. Three of the four states (Texas, Florida, and North Carolina) have developed RBSLs specifically for commercial/industrial sites for at least one medium. None of the four states had developed RBSLs for soil gas, and none provided guidance on evaluating the significance of contaminant concentrations in soil gas. Therefore, the degree to which soil gas concentrations posed an inhalation risk to onsite receptors was initially assessed by comparing them to Occupational Safety and Health Administration (OSHA) 8-hour time-weighted-average permissible exposure limits (PELs) (National Institute of Occupational Safety and Health [NIOSH], 1997) and time-weighted-average threshold limit values (TLVs) determined by the American Conference of Governmental Industrial Hygienists (1996).

COPCs that exceeded RBSLs in at least one sample are summarized by medium in Table 3.1. Benzene was the most common COPC (a groundwater COPC at five of the nine sites), and generally was the “risk-driver” due to its relative toxicity and mobility relative to the other organic COPCs. The polynuclear aromatic hydrocarbons (PAHs) benzo(b)fluoranthene and benzo(k)fluoranthene were COPCs only at Pope AFB Site ST-08, where the contaminant was #2 fuel oil.

**TABLE 3.1**
**SUMMARY OF CHEMICALS OF POTENTIAL CONCERN**

| Analyte | Number of sites at which Analyte was Identified as a COPC[a] | | |
|---|---|---|---|
| | Soil | Groundwater | Soil Gas |
| Benzene | 2 | 5 | 2 |
| Ethylbenzene | 1 | 4 | 0 |
| Toluene | 0 | 2 | 1 |
| Xylenes | 1 | 4 | 1 |
| MTBE[b] | 0 | 1 | --[c] |
| Naphthalene | 0 | 3 | -- |
| Benzo(b)fluoranthene | 0 | 1 | -- |
| Benzo(k)fluoranthene | 0 | 1 | -- |
| Lead | 0 | 4 | -- |
| TPH [d] | 0 | 3 | -- |

[a] COPC = Chemical of potential concern.
[b] MTBE = Methyl tertiary butyl ether.
[c] "--" = Analyte not identified as a COPC.
[d] TPH = Total petroleum hydrocarbons.

## 3.3 NATURAL ATTENUATION ANALYSIS

At almost all of the sites, resampling of previously sampled locations indicated that organic contaminant concentrations in soil were decreasing over time. At five of the sites, the decrease could be attributed to the effects of weathering combined with engineered source reduction (bioventing, SVE, in-well DDC aeration, or product recovery) (see Appendix C ). At the remaining two sites for which historical soil data were available, the decrease was attributed to natural weathering alone. At six of the nine sites (including three sites where engineered source reduction had been performed), historical groundwater quality data indicated that organic COPC concentrations were decreasing over time (Appendix C ). Historical groundwater sampling data indicated that:

- Five of the 11 organic contaminant plumes sampled (two of the nine sites had two plumes each) appeared to be stable (neither expanding or receding to a significant degree);

- Two plumes appeared to be receding;

- The second-youngest plume (Seymour Johnson AFB) appeared to have expanded in the recent past; and

- Insufficient data were available to assess the stability of three of the plumes.

Groundwater assimilative capacities computed for each of the organic COPCs at the nine sites ranged from 3.0 milligrams per liter (mg/L) to 20.4 mg/L and averaged 10.7 mg/L. The assimilative capacity computed for the groundwater systems at eight of the nine sites exceeded the maximum total concentrations of COPCs, indicating that the aquifers theoretically have sufficient electron acceptor capacity to degrade the available organic COPC mass as a single pore volume of groundwater migrates through the contaminated area. At the remaining site (Eglin AFB Seventh Street Service Station), the computed BTEX assimilative capacity was approximately 13,000 µg/L, and the maximum detected dissolved BTEX concentration was 26,000 µg/L. Therefore, multiple pore volume flushes would be required to degrade the available COPC mass at this site. Biodegradation rates computed for the COPCs are summarized in Table 3.2. Based on the geometric mean decay rates, half-lives for COPCs ranged from 0.3 to 2.7 years.

**TABLE 3.2**
**RANGE OF BIODEGRADATION RATES FOR COPCs**

| COPC[a/] | Number of Plumes for Which Rates Were Computed | Range ($day^{-1}$)) | Geometric Mean ($day^{-1}$) | Half Life (Years) |
|---|---|---|---|---|
| Total BTEX[b/] | 3 | 0.01-0.0026 | 0.005 | 0.4 |
| Benzene | 6 | 0.002-0.0067 | 0.004 | 0.5 |
| Toluene | 2 | 0.0027-0.017 | 0.007 | 0.3 |
| Ethylbenzene | 3 | 0.006-0.001 | 0.003 | 0.6 |
| Xylene | 2 | 0.0073-0.0033 | 0.005 | 0.4 |
| Napthalene | 1 | 0.0007 | 0.0007 | 2.7 |

[a/] COPC = Chemical of potential concern.
[b/] BTEX = Benzene, toluene, ethylbenzene, and xylenes.

## 3.4 CONTAMINANT FATE AND TRANSPORT

The fate and transport of dissolved organic COPCs in nine plumes at seven of the sites was assessed using the analytical model BIOSCREEN (Newell *et al*., 1996). Typically, the migration and/or persistence of benzene was simulated because of its relative toxicity and mobility. At two sites, the migration of dissolved xylenes also was simulated due to high concentrations of this compound in the groundwater (Appendix C ).

BIOSCREEN simulations for four of the nine plumes for which contaminant migration was simulated predicted that the dissolved COPC plume would expand in the downgradient direction in the future without additional engineered remedial action. Historical groundwater quality data for these four sites had indicated that one of the plumes was stable, one was expanding, and plume dynamics at the remaining two could not be ascertained based on the available data (Appendix C ). Four of the remaining

plumes were simulated to be stable or receding, and the simulated plume dynamics at the ninth site could not be compared to a field-measured plume because the actual plume had not been fully delineated.

Based on the BIOSCREEN model results, the time for concentrations of COPCs to decrease below Tier 1 RBSLs without additional engineered remedial action varied from 1 year to more than 400 years, with a median value of 10 years (including results from both the first-order decay and instantaneous-reaction routines). Predicted compliance times using the instantaneous reaction routine were at least 40 percent faster than the first-order decay routine, most likely because the first-order decay routine assumes no biodegradation of dissolved constituents in the source zone.

For two sites, the BIOSCREEN model also was used to predict the plume behavior assuming that 80 percent of the contaminant source was removed over a period of 3 years via engineered remediation. The simulated effect of engineered source reduction was more rapid plume diminishment. The results of these simulations indicated that the time to achieve Tier 1 RBSLs would be reduced by 75 to 85 percent.

## 3.5 TIER 2 SCREENING

In cases where maximum concentrations of one or more target analytes exceeded Tier 1 RBSLs, the generic (default Tier 1) exposure scenarios were re-evaluated in a Tier 2 assessment. Tier 2 site-specific target levels (SSTLs) were calculated based on more realistic, site-specific exposure scenarios. Each of the nine streamlined RBCA sites was located on an active Air Force Base in a commercial/industrial area where institutional controls on land use could be enforced. Therefore, there were no current or expected completed exposure pathways to ecological receptors. None of the dissolved contaminant plumes were projected to impact groundwater or surface water supplies used for potable, irrigation, or industrial purposes, and surface soils generally were not impacted. The land use at each of the sites was projected to remain commercial/industrial. Therefore, realistic exposure scenarios generally included dermal exposure and inhalation risks posed to intrusive construction workers and aboveground site workers. In some cases, risks posed by incidental ingestion of contaminated soil or groundwater also were considered per state guidance.

The procedures and algorithms used to calculate Tier 2 SSTLs evolved over the course of the project. In the end, groundwater SSTLs were developed using guidelines set forth by ASTM (1995) and the US Environmental Protection Agency (USEPA, 1989, 1991, 1993, and 1997). The method used to calculate soil gas SSTLs was also based on the ASTM (1995) guidelines. The soil gas SSTLs for indoor inhalation exposure were calculated by estimating a site-specific attenuation factor that accounts for diffusion through the unsaturated zone and building foundation and dilution and mixing with air in an overlying building. After an acceptable risk-based indoor air concentration is established, the attenuation factor is applied to calculate an acceptable soil vapor concentration. The attenuation factor was derived using the Johnson and Ettinger (1991) model. SSTLs for soil were calculated using algorithms recommended by USEPA (1989 and 1992). In addition, recent updates from the USEPA Superfund Dermal Work Group were used to calculate soil SSTLs for the dermal contact exposure route.

Maximum detected contaminant concentrations exceeded Tier 2 SSTLs at only two sites (Appendix C ). At one site, the groundwater benzene concentration exceeded the SSTL calculated to be protective of intrusive construction workers. At another site, the benzene concentration in soil gas exceeded the concentration calculated to be protective of future indoor receptors in the event that a regularly-inhabited building was constructed on top of the source area in the future. In summary, out of a total of 36 COPCs at the nine sites (Table 3.1), only two were deemed to be COCs based on realistic exposure assumptions.

The Tier 1 RBSLs and Tier 2 SSTLs for the BX Service Station at Tyndall AFB provide an example of how site-specific exposure assumptions can cause Tier 2 SSTLs to deviate from RBSLs (Table 3.3). The groundwater RBSLs are based on an assumption of unrestricted future use of the groundwater (i.e., use as a drinking water source). In contrast, the SSTLs computed for this site assume only minimal, incidental ingestion of groundwater at a rate of 0.04 liter per 8-hour day for a maximum of 46 days during the course of a construction project. These exposure parameters were developed by the Air Force for use at Eglin AFB, Florida, and have been reviewed and approved by FDEP.

The significance of the detected dissolved lead concentrations was evaluated using the USEPA (1994) Integrated Exposure Uptake Biokinetic (IEUBK) model, which provides an estimate of potential blood lead levels in children associated with exposure to all site media. This model indicated that the impacts of lead in soil and groundwater at the Tyndall AFB BX Service Station are not considered to be significant.

**TABLE 3.3**
**GROUNDWATER SSTLS FOR TYNDALL AFB BX SERVICE STATION**

| Analyte | Matrix | Units[a/] | Maximum Detected Concentration | Tier 1 RBSL[b/] | Tier 2 RME SSTL[c/] |
|---|---|---|---|---|---|
| Benzene | Groundwater | μg/L | 3,400 | 1 | 2,980 |
| Toluene | Groundwater | μg/L | 5,000 | 40 | 126,000 |
| Ethylbenzene | Groundwater | μg/L | 3,100 | 30 | 53,300 |
| Xylenes | Groundwater | μg/L | 16,000 | 20 | 1,160,000 |
| TRPH [d/] | Groundwater | mg/L | 41 | 5 | --[e/] |
| Lead | Groundwater | μg/L | 62 | 15 | -- |
| Naphthalene | Groundwater | μg/L | 320 | 20 | 26,000 |
| MTBE [d/] | Groundwater | μg/L | 1,300 | 35 | 41,800 |

[a/] μg/L = micrograms per liter; mg/L = milligrams per liter.
[b/] RBSL = generic residential risk-based screening level from FDEP (1997).
[c/] RME SSTL = reasonable maximum exposure site-specific target level.
[d/] TRPH = total recoverable petroleum hydrocarbons, MTBE = methyl tertiary butyl ether.
[e/] “--" = SSTL could not be computed.

## 3.6 PROPOSED REMEDIAL ALTERNATIVES

MNA with institutional controls was evaluated as a potential remedial alternative at all sites. Engineered source reduction (in addition to engineered source reduction actions already being implemented) was evaluated for two sites because the fate and transport modeling predicted that Tier 1 RBSLs for groundwater COPCs would not be achieved within 10 years. In these two cases, the average cost for implementing source reduction combined with MNA and institutional controls was approximately $500,000, compared to $240,000 for MNA with institutional controls alone. The recommended remedial alternatives for the nine sites were as follows:

- Immediate site closure (Kelly AFB);
- Closure contingent on the results of future LTM (Eglin AFB Military Gas Station, Tyndall AFB Site FT-16, Keesler AFB, and Randolph AFB);
- Continued free product recovery until recoverable product is extracted, followed by site closure (Seymour Johnson AFB);
- MNA until SSTLs are achieved, followed by an inactive (but managed) status characterized by 5 years of monitoring (Tyndall AFB BX Service Station); and
- MNA combined with source area biosparging and SVE (Eglin AFB Seventh Street Service Station).

Remedial recommendations were not required for the Pope AFB site because our scope was limited to a risk-based characterization of the site.

## 3.7 LONG-TERM MONITORING

Of the sites where MNA was recommended, LTM consisted of monitoring an average of seven wells for an average of 9 years. Constituents recommended for analysis included the site COPCs, and geochemical natural attenuation indicator parameters. The recommended frequency of LTM ranged from quarterly to biennially (every other year) (Appendix C ).

## 3.8 CURRENT STATUS OF SITES

The Kelly AFB site was granted immediate closure. Justification for site closure included the following:

- The plume is stable and has not migrated off-site;
- The current and expected future use of the site is as an industrial facility;
- The lack of beneficial use of the affected groundwater, which resides in a low-permeability aquitard;

- Remaining contaminant concentrations are protective for construction worker exposure; and

- Future monitoring of the site would occur as part of the Base-wide monitoring program.

The Randolph and Keesler AFB sites were granted closure contingent on the results of 2 to 5 years of LTM. The remaining six sites are still in regulatory or Air Force review, and final decisions regarding site closure have not been made.

# SECTION 4

# COST ANALYSIS

The average cost for implementing the streamlined RBCA process at the four sites is outlined in Table 4.1.

**TABLE 4.1**
**AVERAGE STREAMLINED RBCA SITE COSTS**

| Labor | Actual Average Cost | Average Cost Assuming Geoprobe® Rental and Subcontracted Drilling |
|---|---|---|
| Kickoff Meeting/Site Visit | $2,300 | $2,300 |
| Work Plan[a/] | $6,400 | $6,400 |
| Field Site Characterization | $6,100 | $6,200 |
| Data Analysis and Reporting[b/] | $14,800 | $14,800 |
| Final Regulatory Meeting | $2,300 | $2,300 |
| Other Direct Costs | | |
| Subcontractors[c/] | $4,100 | $4,700 |
| Travel[d/] | $1,500 | $1,500 |
| Field Equipment and Supplies | $800 | $3,200 |
| Other[e/] | $1,200 | $1,200 |
| Project Management[f/] | $4,000 | $4,000 |
| **Average Cost per Site** | $43,500 | $46,600 |

a/ Includes draft and final versions, and gathering/analyzing available site data.
b/ Includes fate and transport modeling, calculating SSTLs, and draft and final report.
c/ Includes analytical laboratory and surveyor.
d/ Includes travel for meetings and field work.
e/ Includes shipping, reproduction, phone/facsimile, and computer usage.
f/ Includes monthly reporting, project controls, and subcontract management.

It should be noted that an AFCEE-owned Geoprobe® was used at most of the sites. The actual average costs in Table 4.1 reflect the use and upkeep of the Geoprobe®; however, there were no rental costs associated with its use. In addition, costs incurred for use of the US Army Corps of Engineers drilling rig at Kelly AFB are not reflected in the actual costs. Therefore, the estimated average costs per site, assuming rental of a Geoprobe® ($3,000 per week for one week) and use of a drilling subcontractor for Kelly AFB ($5,500), are also shown in the table. Project management costs include the preparation of detailed monthly reports for 27 months; the cost of this task could be reduced for sites where this level of reporting is not required.

# SECTION 5

# LESSONS LEARNED AND RECOMMENDATIONS

## 5.1 SITE CHARACTERIZATION

The site characterization should focus on meeting state-specific regulatory requirements and on obtaining sufficient data to defensibly support risk-based corrective action recommendations. Key characterization needs include resampling previously-sampled locations to assess the temporal variation in contaminant concentrations, identifying maximum contaminant concentrations, determining the downgradient extent of dissolved contaminant migration, determining the locations of potential receptor exposure points (e.g., water supply wells, surface water bodies, wetlands), and determining background and plume core concentrations of geochemical natural attenuation indicator parameters.

Site characterization costs can be reduced through the use of direct-push techniques to advance soil borings, collect subsurface soil samples, and install small-diameter monitoring points, and the use of field geochemical test kits in place of more expensive fixed-base laboratory analyses.

## 5.2 FATE AND TRANSPORT MODELING

Use of relatively simple, user-friendly analytical fate and transport models such as BIOSCREEN often is sufficient to estimate the persistence and migration of the dissolved plume. The ability of these types of models to simulate spatial heterogeneities in the aquifer or the contaminant source the effects of weathering and engineered source reduction is limited. However, the nearly ubiquitous occurrence of fuel hydrocarbon biodegradation is increasingly recognized by the regulatory community; therefore, use of simple screening models often is acceptable despite their limitations.

## 5.3 RISK ASSESSMENT

Performance of a streamlined risk assessment is benefited by early identification of and agreement on potential receptors, exposure pathways, and exposure parameters.

The analytical model(s) should adequately address the exposure scenario(s) of interest. For example, a widely accepted model for estimating volatilization from soil or groundwater into an excavated trench does not exist. Therefore, simplifying/conservative assumptions need to be made to assess potential risk to an intrusive worker via the inhalation exposure route. Both the USEPA (1996) *Soil Screening Guidance* and the ASTM (1995) RBCA standard present equations that can be used to address soil-to-groundwater leachability, volatilization of chemicals from surface soil to outdoor air, and

volatilization of chemicals from subsurface soils to indoor air. For a particular exposure scenario (e.g., inhalation of chemicals volatilized from groundwater into indoor air), fate/transport algorithms may only be available from a particular source (e.g., ASTM RBCA guidance).

The regulatory acceptance of analytical exposure models should be determined prior to use of such models. For example, does the regulatory agency accept the ASTM (1995) RBCA approach for assessing potential risks/hazards at petroleum-contaminated sites? Does the regulatory agency require the use of alternate algorithms for estimating exposure via a specific exposure route? Does the regulatory agency have specific RBCA guidance/algorithms? For example, the State of Florida requires the use of their algorithm derived to assess the potential risk/hazard from breathing chemicals volatilized from groundwater within an excavated trench.

Analytical models used to assess risk should be up-to-date and scientifically defensible. Recently a USEPA Superfund national dermal workgroup has updated the recommended approaches for assessing risks/hazards from dermal exposure to chemicals in soil and groundwater. Recent developments in exposure modeling can be viewed on the web page of the USEPA National Center of Environmental Assessment and the USEPA Superfund web page.

For the soil/groundwater-to-indoor/outdoor air volatilization pathway, it is possible to reduce the uncertainty by collecting and quantitatively analyzing soil gas samples. The ASTM (1995) RBCA models and/or the USEPA (1999) Superfund models can be modified to use soil gas vapor results directly, thereby significantly reducing the uncertainty associated with modeling volatilization of chemicals from soil into the soil pore space (i.e., the initial step of the model is eliminated).

## 5.4 VALUE OF SOURCE REDUCTION

- Without source reduction, groundwater contaminants at most sites would have exceeded Tier 1 cleanup goals for over 20 years.
- Regulatory agencies are more likely to accept monitored natural attenuation as a groundwater remedy at sites where active source reduction has occurred.
- Source reduction also reduces the risks to future intrusive workers and allows the site to be used with less institutional control.

## 5.5 GENERAL IMPLEMENTATION

- The closure process for petroleum contaminated sites is being streamlined by many states.
- The ability to limit receptor exposure to contamination via enforceable institutional controls is an important element in obtaining site closure agreements.
- It is feasible to perform the entire RBCA process, including a MNA assessment, for less than $50,000 per site.

- Whenever possible, the RBCA process should be used to facilitate site closure at low-risk, petroleum-contaminated sites where future land use is primarily industrial commercial.

# SECTION 6

# REFERENCES


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# APPENDIX A

# CASE STUDY 1 – KEESLER AFB

# BASE EXCHANGE SERVICE STATION, AOC-1 (ST-06)

**Keesler Air Force Base Base Exchange Service Station, AOC-A (ST-06)** **Site Name**

# SITE INFORMATION

## IDENTIFYING INFORMATION

**Site Name**: Base Exchange Service Station, Area of Concern – A (ST-06)

**Location**: Keesler Air Force Base, Mississippi

**CERCLIS ID No.**: NA

Regulatory Context: Lead agency is USEPA Region IV; however, UST-related guidelines and requirements of the Mississippi Dept. of Environmental Quality are being used. IRP site characterization report completed in 1991, and RCRA Facility Investigation Report completed in 1992.

## TECHNOLOGY APPLICATION

**Period of Performance**: September 1997 – April 1999

**Area of Contaminated Zone (source area plus dissolved plume)**: 4.0 acres

## BACKGROUND

**Waste Management Practice That Contributed to Contamination**: leaking underground storage tank(s)

**Site History**: 10 MOGAS USTs removed in 1987; evidence of contamination showed that one or more of the tanks had leaked.

**Remedy Selection**: Bioventing system installed in 1993 and operated for 3 years. Density-driven convection (DDC) in-well aeration system installed in 1996 and operated at least through February 1998. Based on this RBCA analysis, recommended final remedial action is monitored natural attenuation because the site contamination does not currently (and will not in the future) pose a significant risk to potential receptors, the dissolved plume is stable and degrading, and institutional controls can be maintained with a high level of confidence.

## SITE LOGISTICS/CONTACTS

(Provide name, address, telephone, e-mail)

**Site Lead**: Ms. Lisa Noble, 81st CES/CEVR, 508 L Street, Keesler AFB, MS 39534-2115, (601)377-5803, noblel@ces.kee.aetc.af.mil.

**Oversight**: Mr. Jim Gonzales, AFCEE/ERT, 3207 North Rd., Building 532, Brooks AFB, TX 78235-5363, (210) 536-4324, james.gonzales@hqafcee.brooks.af.mil.

**Regulatory Contact**: Mr. Robert Pope, USEPA Region IV, 61 Forsyth St., SW, Atlanta, GA 30303-3104, (404) 562-8506.

Mr. Bob Merrill, Mississippi DEQ, P.O. Box 10385, Jackson, MS 39289-0385, (601) 961-5171.

**Prime Contractor**: Mr. John Hicks, Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, (303) 831-8100, john.hicks@parsons.com

**Additional Contacts**: NA

# MATRIX DESCRIPTION

## MATRIX IDENTIFICATION

**Type of Matrix Processed Through Technology System**: RBCA study addressed soil, groundwater, and soil gas

## CONTAMINANT CHARACTERIZATION

**Primary Contaminant Groups and Concentrations Measured During Site Investigation**:
Gasoline constituents, see attached Table 1 for concentrations of target analytes in soil and attached Figure 1 for distribution of total lead and BTEX in groundwater.

**Contaminant Properties**:

Based on Tier 1 screening, only lead in groundwater was identified as a contaminant of potential concern at the BX Service Station. Lead is a non-soluble, non-volatile element that is extremely persistent in both soil and water. Environmental processes may transform one lead compound to another; however, lead itself is not degraded.

## MATRIX CHARACTERISTICS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant parameters for the application)

| Parameter | Value | Measurement Procedure |
|---|---|---|
| Soil Classification | NA | NA |
| Clay Content and/or Particle Size Distribution | NA | NA |
| Additional Soil Characteristics (specify) | NA | NA |

## SITE GEOLOGY/STRATIGRAPHY/HYDROGEOLOGY

Describe heterogeneity, depth to groundwater, size and characteristics of applicable aquifers and units (especially important for in situ technologies)

Fine- to medium-grained sand to 20 feet below ground surface (bgs), underlain by a clay layer of unknown thickness. Groundwater present at 5 to 9 feet bgs. Average hydraulic conductivity of sand zone is 40 ft/day, calculated horizontal groundwater flow velocity is 0.8 ft/day.

# TECHNOLOGY SYSTEM DESCRIPTION

## PRIMARY TECHNOLOGY

Monitored natural attenuation

## SUPPLEMENTAL TECHNOLOGY TYPES

Bioventing and density-driven convection in-well aeration

# TABLE 1
# SUMMARY OF SOIL ANALYTICAL DATA
## BX Service Station, Area of Concern A (ST-06)
## Keesler AFB
## Biloxi, Mississippi

| | | Sample Locations, Intervals, and Dates | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | SBA-14 (7 - 8)[a/] 17-Feb-98 | SBA-14 (9 - 11) 18-Feb-98 | SBA-15 (9 - 10) 18-Feb-98 | SBA-16 (11 - 12) 18-Feb-98 | SBA-16 (9 - 10) 18-Feb-98 | WEI-B3 SBA-17 (9.5 - 10.5) 18-Feb-98 | SBA-18 (8.5 - 9.5) 18-Feb-98 | WEI-B1 SBA-19 (6.5 - 8) 18-Feb-98 | SBA-19 (8.5 - 10) 18-Feb-98 | SBA-100 (8.5 - 10) 18-Feb-98 | SBA-20 (6 - 7) 18-Feb-98 | SBA-20 (9.5 - 10.5) 18-Feb-98 |
| | | | | | | | | | | | | | |
| Benzene | mg/Kg[b/] | 0.0054U | 0.017 | NM | NM | NM | 0.22 | 5.4U | 0.0055U | 0.28U | 0.37U[c/] | 4.6U | 2.4U |
| Ethylbenzene | mg/Kg | 0.0022U | 0.0089 | NM | NM | NM | 0.09 | 4.2 | 0.0022U | 0.28U | 0.15U | 1.9 | 0.95U |
| Toluene | mg/Kg | 0.0054U | 0.072 | NM | NM | NM | 0.75 | 12 | 0.0055U | 0.11U | 0.37U | 4.6U | 2.4U |
| Xylenes (total) | mg/Kg | 0.0054U | 0.034 | NM | NM | NM | 0.58 | 150 | 0.0055U | 0.28U | 0.37U | 3.1J1[d/] | 10 |
| Total BTEX | mg/Kg | 0.0184U | 0.1319 | NM | NM | NM | 1.64 | 166.2 | 0.0187U | 0.95U | 1.26U | 5 | 10 |
| | | | | | | | | | | | | | |
| Naphthalene | mg/Kg | NM | 0.26U | NM | NM | NM | 0.27 | 2.1 | 0.22U | 0.12J1 | 0.22U | NM | 10 |
| | | | | | | | | | | | | | |
| Lead | mg/Kg | NM | 0.46J[e/] | 0.40J | NM | 0.18J | 0.34J | 8.7 | 4.2 | NM | 2.2 | 1.1 | 7.4 |
| | | | | | | | | | | | | | |
| Total Organic Carbon | mg/Kg | NM | NM | 2000U | 2970 | 2000U | NM | NM | NM | NM | NM | NM | NM |
| | | | | | | | | | | | | | |

Notes:

a/ depth in feet below ground surface.

b/ mg/kg = Milligrams per kilogram.

c/ U = The analyte was analyzed for and is not present above the reporting limit.

d/ J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.

e/ J = The analyte was positively identified, but the associated numerical value may not be consistent with the amount actually present in the environment. The data should be considered as a basis of decision-making and are usable.

Analysis methods are SW7421 for lead, SW8020 for aromatic VOCs, and SW9060 for total organic carbon.

SBA-100 (8.5-10) is a duplicate of SBA-19 (8.5-10)

All analyses performed by Quanterra Laboratories of Arvada, Colorado

NM = Not Measured

BTEX = Benzene, Toluene, Ethylbenzene, and Total Xylenes

## REMEDIAL SYSTEM DESCRIPTION AND OPERATION

A total of 9 monitoring wells will be sampled quarterly for 1 year, and then annually for 4 years to document the effects of natural attenuation and ensure that downgradient receptors are protected. Samples will be analyzed for aromatic volatile organics and geochemical natural attenuation indicator parameters. If the 5-year monitoring period confirms that contamination has remained below target cleanup levels, performance monitoring will cease and the site will be placed in an inactive (but managed) status.

## OPERATING PARAMETERS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant operating parameters for the application.)

| Parameter | Value |
|---|---|
| Example: Temperature | NA |
| Others (as appropriate) | NA |

## TIMELINE

(Provide dates for key activities for the application, focusing on events related to technology.)

| Start Date | End Date | Activity |
|---|---|---|
| August 1997 | August 1997 | Kickoff Meeting |
| Sept. 1997 | Nov. 1997 | Project Work Plan (draft and final) |
| Feb. 1998 | Feb. 1998 | Field Site Characterization |
| March 1998 | April 1999 | Data Analysis and Corrective Action Plan (draft and final) |
| 1999 | 2004 | Long-term Monitoring |

# TECHNOLOGY SYSTEM PERFORMANCE

## CLEANUP GOALS/STANDARDS

Typical cleanup levels for soil and water at gasoline UST sites in Mississippi are 100 ppm BTEX and 18 ppm BTEX, respectively. In addition, the Mississippi Department of Environmental Quality (MDEQ) has developed generic, risk-based screening levels (RBSLs) that are available on “look-up” tables. The RBSLs vary according to the distance of the nearest receptor from the source area. The closest receptor to the site is the Back Bay of Bixoxi, located approximately 2,100 feet northeast of the site. The MDEQ look-up tables have RBSLs for receptors located 1,400 feet and 2,600 feet from the source. To be conservative, the 1,400-foot RBSLs were selected as the appropriate set of Tier 1 screening values. However, these values do not include a RBSL for lead. The USEPA (1994a) Office of Solid Waste directive on risk assessment and cleanup of residential soil lead recommends that soil lead levels less than 400 ppm be considered safe for residential use; this level was used as the RBSL for lead in soil. Table 2 compares the maximum site concentrations for each compound measured in soil to the appropriate RBSL.

As with soil, the 1,400-foot receptor RBSLs were selected as the appropriate set of Tier 1 screening values for groundwater. In addition, the USEPA MCL for lead of 15 µg/L was used as the RBSL for this constituent. Table 3 compares the maximum site concentrations for each compound measured in groundwater to the appropriate RBSL.

Maximum-detected concentrations of BTEX in soil gas were compared to the chemical-specific OSHA 8-hour time-weighted average PELs (Table 4).

Based on the above-described comparisons, only lead in groundwater was identified as a chemical of potential concern for the BX Service Station. The USEPA (1994b) Integraded Exposure Uptake Biokinetic (IEUBEK) model, which provides an estimate of potential blood lead levels in residential children associated with exposure to all site media (soil and

**TABLE 2**
**COMPARISON OF MAXIMUM SITE SOIL CONCENTRATIONS**
**TO TARGET CLEANUP LEVELS**
**BX Service Station, Area of Concern A (ST-06)**
**Keesler AFB**
**Biloxi, Mississippi**

| Chemical Name | Units | Maximum Concentration Detected | Location of Maximum Detection | Date of Maximum Detection | Target Levels[a/] | Number of Times Exceeded |
|---|---|---|---|---|---|---|
| Total BTEX | mg/kg[b/] | 166.2 | SBA-18 | 18-Feb-98 | 100 | 1 |
| Lead | mg/kg | 8.7 | SBA-18 | 18-Feb-98 | 400 | 0 |
| Acenaphthene | mg/kg | NA[c/] | NA | NA | > res[d/] | 0 |
| Acenaphthylene | mg/kg | NA | NA | NA | > res | 0 |
| Anthracene | mg/kg | NA | NA | NA | > res | 0 |
| Benzene | mg/kg | 0.22 | SBA-17 | 18-Feb-98 | > res | 0 |
| Benzo(b)fluoranthene | mg/kg | NA | NA | NA | > res | 0 |
| Benzo (g,h,i)perylene | mg/kg | NA | NA | NA | > res | 0 |
| Benzo(k)fluoranthene | mg/kg | NA | NA | NA | > res | 0 |
| Benzo(a)pyrene | mg/kg | NA | NA | NA | > res | 0 |
| Chrysene | mg/kg | NA | NA | NA | > res | 0 |
| Dibenzo(a,h)anthracene | mg/kg | NA | NA | NA | > res | 0 |
| Ethylbenzene | mg/kg | 4.2 | SBA-18 | 18-Feb-98 | > res | 0 |
| Fluoranthene | mg/kg | NA | NA | NA | > res | 0 |
| Fluorene | mg/kg | NA | NA | NA | > res | 0 |
| Indeno(1,2,3-cd)pyrene | mg/kg | NA | NA | NA | > res | 0 |
| Naphthalene | mg/kg | 10 | SBA-20 | 18-Feb-98 | > res | 0 |
| Phenanthrene | mg/kg | NA | NA | NA | > res | 0 |
| Pyrene | mg/kg | NA | NA | NA | > res | 0 |
| Toluene | mg/kg | 12 | SBA-18 | 18-Feb-98 | > res | 0 |
| Xylenes, Total | mg/kg | 150 | SBA-18 | 18-Feb-98 | > res | 0 |

Notes: Shading indicates maximum site concentration is above target level.

[a/] Total BTEX based on MDEQ Typical Cleanup Level (Table 1.1), lead based on USEPA (1994c), all other Target Levels based on MDEQ RBSL "look-up" tables and a distance to receptor of 1,400 feet.

[b/] mg/kg = Milligrams per kilogram.

[c/] NA = Not available.

[d/] > res = the RBSL exceeds the expected soil residual contamination under free product (worst case) conditions.

**TABLE 3**
**COMPARISON OF MAXIMUM SITE GROUNDWATER CONCENTRATIONS TO TARGET CLEANUP LEVELS**
**BX Service Station, Area of Concern A (ST-06)**
**Keesler AFB**
**Biloxi, Mississippi**

| Chemical Name | Units | Maximum Concentration Detected | Location of Maximum Detection | Date of Maximum Detection | Target Levels[a] | Number of Times Exceeded |
|---|---|---|---|---|---|---|
| Total BTEX | μg/L [b] | 22,400 | MW8-3 | 20-Feb-98 | 18,000 | 1 |
| Total Lead | μg/L | 21 | MW8-3 | 20-Feb-98 | 15 | 3 |
| Acenaphthene | μg/L | 1 | MWA-11 | 20-Nov-92 | >sol[e] | 0 |
| Acenaphthylene | μg/L | 10 U[c] | NA[d] | 20-Nov-92 | >sol | 0 |
| Anthracene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Benzene | μg/L | 2,500 | MW8-3 | 20-Feb-98 | 56,000 | 0 |
| Benzo(b)fluoranthene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Benzo (g,h,i)perylene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Benzo(k)fluoranthene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Benzo(a)pyrene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Chrysene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Dibenzo(a,h)anthracene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Ethylbenzene | μg/L | 1,700 | MW8-3 | 20-Feb-98 | >sol | 0 |
| Fluoranthene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Fluorene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Indeno(1,2,3-cd)pyrene | μg/L | 10 U | NA | 20-Nov-92 | 150.00 | 0 |
| Naphthalene | μg/L | 320 | MW8-3 | 19-Nov-92 | >sol | 0 |
| Phenanthrene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Pyrene | μg/L | 10 U | NA | 20-Nov-92 | >sol | 0 |
| Toluene | μg/L | 10,000 | MW8-3 | 20-Feb-98 | >sol | 0 |
| Xylenes, Total | μg/L | 8,200 | MW8-3 | 20-Feb-98 | >sol | 0 |

Notes: Shading indicates maximum site concentration is above target level.

[a] Total BTEX based on MDEQ Typical Cleanup Level (Table 1.1), lead based on USEPA (1996), all other Target Levels based on MDEQ RBSL "look-up" tables and a distance to receptor of 1,400 feet.

[b] μg/L = Micrograms per Liter.

[c] U = Analyte not detected above corresponding number.

[d] NA = Not available.

[e] >sol = greater than the maximum solubility possible.

**TABLE 4**
**COMPARISON OF MAXIMUM SITE SOIL GAS CONCENTRATIONS TO OSHA PERMISSIBLE EXPOSURE LIMITS**
**BX Service Station, Area of Concern A (ST-06)**
**Keesler AFB**
**Biloxi, Mississippi**

| Chemical | Maximum Detected Concentration (ppmv [a]) | OSHA PEL (ppmv) [b] | Maximum Concentration Above PEL? |
|---|---|---|---|
| Benzene | ND | 1 | No |
| Toluene | .006 M[d] | 200 | No |
| Ethylbenzene | 0.020 | 100 | No |
| Xylenes | 0.041 | 100 | No |
| TPH [e] | 1.943 | -- [f] | -- |

Notes:

[a] ppmv = Parts per million, volume per volume.

[b] Occupational Safety and Health Administration (NIOSH, 1997) 8-hour time-weighted average permissible exposure limit.

[c] ND = Not detected above reporting limits.

[d] M data qualifier indicates potential bias due to matrix interferences.

[e] TPH = Total petroleum hydrocarbons.

[f] "--" = No PEL available.

groundwater contaminated with lead), was used to evaluate the significance of the maximum detected groundwater lead concentration. The modeling results indicated that the impacts of lead in site media on potential future residents are not significant.

### PERFORMANCE DATA AND DATA ASSESSMENT

Analytical data are compared to Tier 1 RBSLs in Tables 2 through 4. Temporal variations in soil contaminant concentrations from 1996 to 1998 (during which time the in-well DDC system was operational) are shown on Figure 2. Total BTEX concentrations measured at all site monitoring wells from 1988 to 1998 indicate substantial oscillation in dissolved BTEX concentrations at the plume core (MW8-3, MW8-4, MW8-5, and MWA-11) during this period have been measured. These oscillations can be attributed to groundwater table fluctuations and the operation of the interim remediation systems since May 1993. The total BTEX plume appears to have been relatively stable, as evidenced by consistent BTEX concentrations in downgradient well MWA-9. In addition, no BTEX concentrations have been detected in cross-gradient and downgradient wells MWA-6, MWA-7, MWA-8, MWA-10, MWA-10B, and MWA-13. Stable plume length indicates that the mass of BTEX input in the groundwater system in the source area is apprroximately equal to the mass of BTEX being removed vial natural attenuation processes.

### PERFORMANCE DATA QUALITY

An electronic Level III validation was performed on the February 1998 analytical results obtained from the fixed-base laboratories. Analytical results associated with non-compliant QC criteria were qualified appropriately.

## COST OF THE TECHNOLOGY SYSTEM

### PROCUREMENT PROCESS

Procurement involved selection of an analytical subcontractor. Bids were obtained from three qualified analytical laboratories, and the selected firm was Quanterra in Wheat Ridge, Colorado.

### COST DATA

(Identify organization that provided cost data and whether cost data are actual or estimated costs)

| Item | Cost ($ Year Basis) | Actual or Estimated (A or E) |
|---|---|---|
| Capital (specify cost/activity) Bioventing | $40,000 | E |
| Operation and maintenance (specify cost/activity) LTM | $15,000 (cost per event) | E |
| Other (specify) | | |

## REGULATORY/INSTITUTIONAL ISSUES

Identify the approvals, licenses, and permits required to operate the technology at the site.

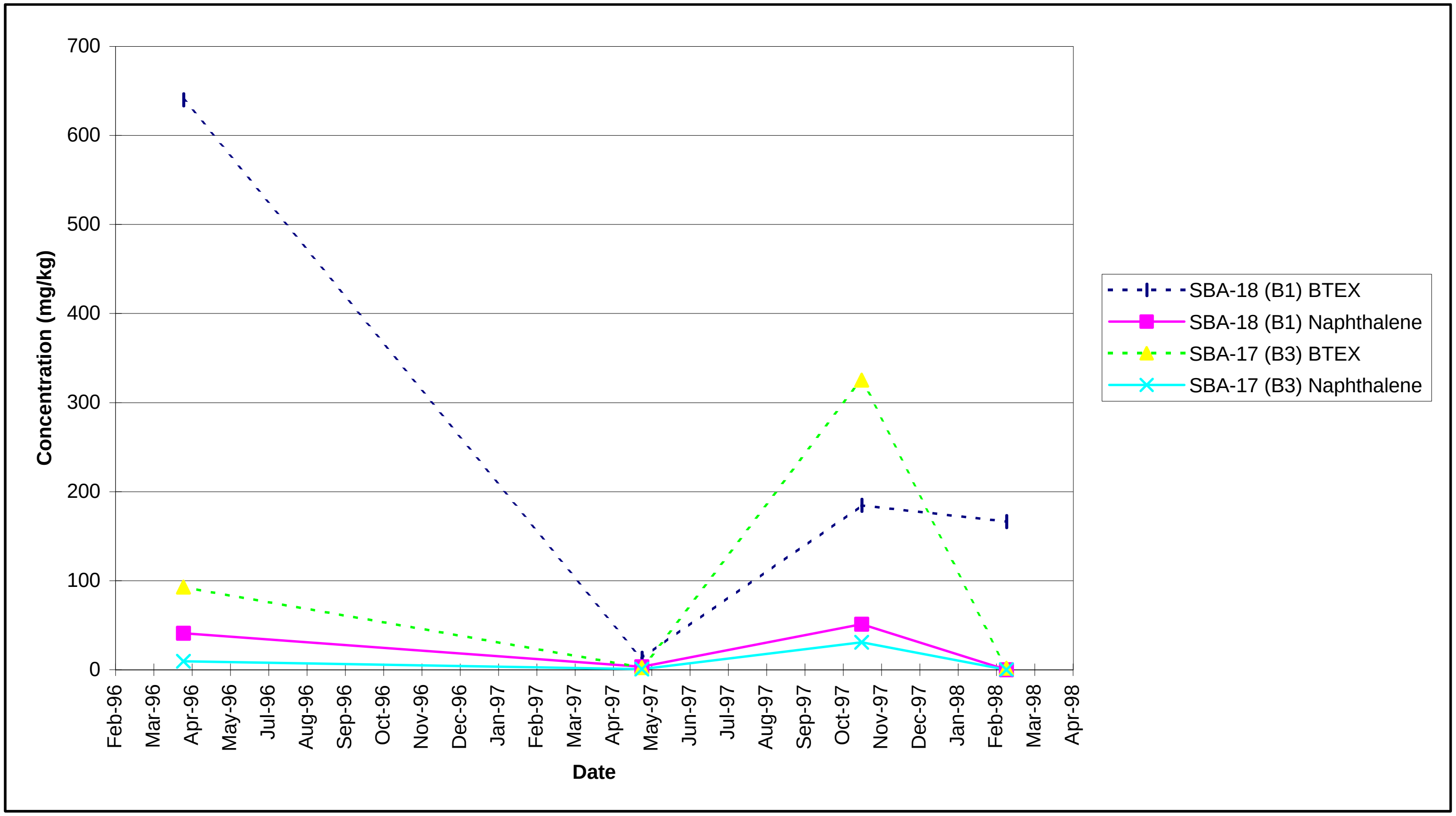
NA

## TECHNOLOGY APPLICABILITY AND ALTERNATIVES

(Provide only for demonstration-scale reports)

Identify technology applicability, competing technologies, and technology maturity; may also discuss commercialization and intellectual property issues.

**FIGURE 2**
**HISTORICAL COMPARISON OF SOIL ANALYTICAL DATA**
**BX Service Station, Area of Concern A (ST-06)**
**Keesler AFB**
**Biloxi, Mississippi**



Remediation by natural attenuation (RNA) is applicable for all petroleum-hydrocarbon contaminated sites. RNA is advantageous for the following reasons:

- Contaminants can be transformed to innocuous byproducts (e.g., carbon dioxide or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally no more effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA can be less costly than conventional, engineered remedial technologies.

A potential disadvantage of RNA is that, in some cases, natural attenuation rates are too slow to make RNA a practical remedial alternative.

# OBSERVATIONS AND LESSONS LEARNED

## COST OBSERVATIONS AND LESSONS LEARNED

Provide observations and lessons learned related to cost of the application.

## PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

The following conclusions were drawn from the risk-based assessment of the site:

- Concentrations of target analytes in all sampled media do not exceed applicable MDEQ RBSLs or OSHA PELs, and detected concentrations of total lead in groundwater do not pose a risk to potential receptors;
- Geochemical data strongly indicate that biodegradation of fuel hydrocarbons is occurring at the site, primarily via the anaerobic processes of sulfate reduction, nitrogen fixation, and methanogenesis;
- Previous and current source removal efforts have reduced hydrocarbon concentrations in vadose zone and saturated zone soils, and the current system does not have an adverse effect on the natural attenuation processes at the site;
- Available data indicate that the dissolved plume is stable, is entirely contained within the existing monitoring well network, and should not impact potential downgradient receptors;
- Keesler AFB is an active base where institutional controls can be maintained with a high level of confidence; and
- None of the potential exposure pathways identified for the site are considered complete.

Per the above conclusions, monitored natural attenuation is appropriate for the BX Service Station.

## OTHER OBSERVATIONS AND LESSONS LEARNED

A long-term monitoring plan was negotiated with the MDEQ and the USEPA Region IV that included monitoring of nine wells for five years. Monitoring will occur quarterly for the first year and annually for the second through fifth years. The purpose of the monitoring is to verify the effectiveness of naturally-occurring remediation processes at limiting plume migration and reducing dissolved contaminant concentrations.

The risk-based corrective action process performed for this site can be used to achieve cost-effective site closure at other relatively low-risk fuel-contaminted sites.

## REFERENCES

**List of references used in preparation of the cost and performance report.**

USEPA, 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities.

USEPA, 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. Office of Emergency and Remedial Response. PEA 540-R-93-081.

## ACKNOWLEDGMENTS

This case study report was prepared by Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, 303-831-8100. The report was prepared for Jim Gonzales at AFCEE/ERT under AETC Contract No. F41689-96-D-0710, Delivery Order 5015.

# APPENDIX B

# CASE STUDY 2 – KEESLER AFB

# FORMER BUILDING 2093 GAS STATION

**Kelly Air Force Base Former Building 2093 Gas Station** **Site Name**

# SITE INFORMATION

## IDENTIFYING INFORMATION

**Site Name**: Former Building 2093 Gas Station, LPST ID No. 93205, Facility ID No. 0038825.

**Location**: Kelly AFB, Texas

**CERCLIS ID No.**: NA

Regulatory Context: Lead agency is the Petroleum Storage Tank (PST) Division of the Texas Natural Resource Conservation Commission (TNRCC).

## TECHNOLOGY APPLICATION

**Period of Performance**: July 1997 – July 1998

**Area of Contaminated Zone (source area plus dissolved plume)**: 1.5 acres

## BACKGROUND

**Waste Management Practice That Contributed to Contamination**: Leaking gasoline USTs and associated piping.

**Site History**: Three MOGAS USTs were integrity tested in 1989, and one failed the test. The USTs and some associated piping were removed in 1991 and were not replaced. Multiple monitoring well installation and groundwater sampling events between 1989 and 1997 indicated the presence of groundwater contamination.

**Remedy Selection**: A 1-year-long bioventing pilot test was concluded in January 1995; the test results indicated that site soils were not sufficiently permeable to enable use of this in situ source reduction technique. Later in 1995, the dispensing islands and remaining below-grade piping were removed, and 2,750 cubic yards of soil in the area of the former tank pad and dispensing islands were excavated. Based on this RBCA analysis, the TNRCC issued a no-further-action memorandum closing the site based on plume stability, the documented occurrence of natural attenuation of fuel residuals, and the conclusion that site contamination does not currently (and will not in the future) pose a significant risk to potential receptors.

## SITE LOGISTICS/CONTACTS

(Provide name, address, telephone, e-mail)

**Site Lead**: Mr. Jerry Arriaga, SA-ALC/EMRO, 301 Tinker Dr., Suite 2, Bldg. 301, Kelly AFB, TX 78241, (210) 925-1819, garriaga@emgate1.kelly.af.mil.

**Oversight**: Mr. Jim Gonzales, AFCEE/ERT, 3207 North Rd., Building 532, Brooks AFB, TX 78235-5363, (210) 536-4324, james.gonzales@hqafcee.brooks.af.mil.

**Regulatory Contact**: Mr. Antonio Pena , Texas Natural Resource Conservation Commission, P.O. Box 13087, Austin, TX, 78711-3087, (512) 239-2200, APENA@tnrcc.state.tx.us.

**Prime Contractor**: Mr. John Hicks, Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, (303) 831-8100, john.hicks@parsons.com

**Additional Contacts**: NA

# MATRIX DESCRIPTION

## MATRIX IDENTIFICATION

**Type of Matrix Processed Through Technology System**: RBCA study addressed soil, groundwater, and soil gas.

## CONTAMINANT CHARACTERIZATION

**Primary Contaminant Groups and Concentrations Measured During Site Investigation**:
Gasoline constituents, see attached Figure 1 for distribution of BTEX in groundwater.

**Contaminant Properties**:

Based on a Tier 1 screening, only benzene in groundwater and soil was identified as a contaminant of potential concern at the former Building 2093 Gas Station. Benzene is volatile, highly soluble in water, and relatively mobile in the groundwater environment. It is also readily biodegradable under both aerobic and anaerobic conditions.

## MATRIX CHARACTERISTICS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant parameters for the application)

| Parameter | Value | Measurement Procedure |
|---|---|---|
| Soil Classification | NA | NA |
| Clay Content and/or Particle Size Distribution | NA | NA |
| Additional Soil Characteristics (specify) | NA | NA |

## SITE GEOLOGY/STRATIGRAPHY/HYDROGEOLOGY

Describe heterogeneity, depth to groundwater, size and characteristics of applicable aquifers and units (especially important for in situ technologies)

The site is underlain by silty clay. A distinct clay unit approximately 3 to 5 feet thick is evident from 35 to 40 feet below ground surface (bgs). Groundwater occurs primarily in silt and possibly caliche seams that produce only small amounts of water. Boreholes that do not intercept one or more water-bearing zones do not yield water. Static groundwater levels range from 5 to 25 feet bgs, depending on location and season. The hydraulic conductivity of the silty clay unit is 0.2 to 0.5 ft/day based on slug tests, and the estimated horizontal groundwater flow velocity is 31 ft/year.

# TECHNOLOGY SYSTEM DESCRIPTION

## PRIMARY TECHNOLOGY

Monitored natural attenuation

**SUPPLEMENTAL TECHNOLOGY TYPES**

Soil excavation

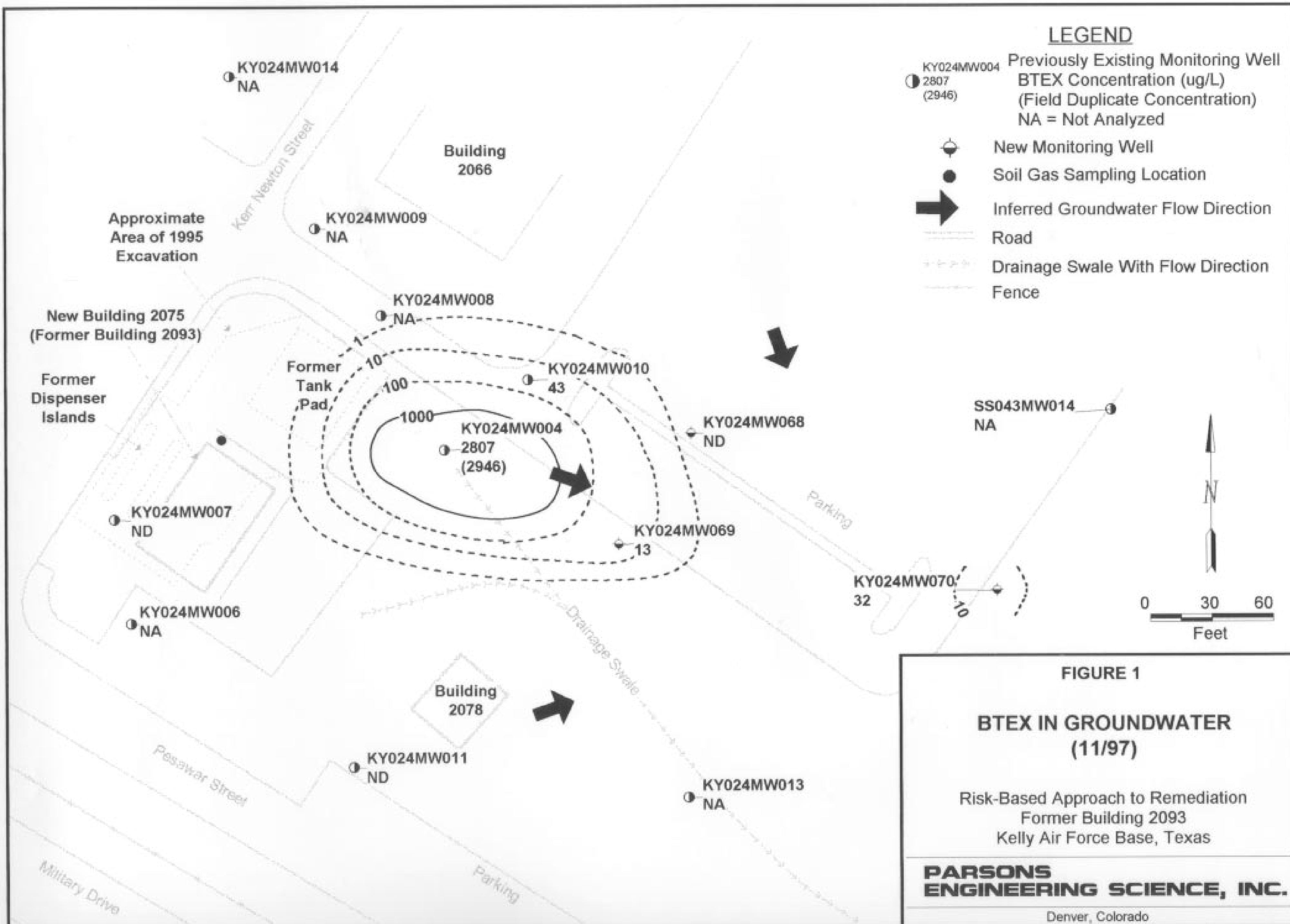



**FIGURE 1**

**BTEX IN GROUNDWATER (11/97)**

Risk-Based Approach to Remediation
Former Building 2093
Kelly Air Force Base, Texas

**PARSONS ENGINEERING SCIENCE, INC.**

Denver, Colorado

FILE NAME: S:\ES\REMED\BIOPLUME\KELLY\FIGURES\MI_WOR\BTEX.WOR DATE: 10/06/99 TIME: 0800

## REMEDIAL SYSTEM DESCRIPTION AND OPERATION

Fate and transport modeling using the analytical code BIOSCREEN (Newell *et al*., 1996) indicated that the maximum migration distance of dissolved benzene from the source area will be approximately 300 feet, and that dissolved benzene concentrations will be below groundwater quality standards within 10 years. Therefore, the site is a candidate for immediate closure according to TNRCC guidance. The Air Force will restrict use of the shallow groundwater at the site until all dissolved benzene concentrations decrease below TNRCC Plan A Category II criterion of 0.0294 mg/L.

## OPERATING PARAMETERS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant operating parameters for the application.)

| Parameter | Value |
|---|---|
| Example: Temperature | NA |
| Others (as appropriate) | NA |

## TIMELINE

(Provide dates for key activities for the application, focusing on events related to technology.)

| Start Date | End Date | Activity |
|---|---|---|
| July 1997 | July 1997 | Kickoff Meeting |
| August 1997 | Nov. 1997 | Project Work Plan (draft and final) |
| Nov. 1997 | Nov. 1997 | Field Site Characterization |
| Dec. 1997 | July 1998 | Data Analysis and Corrective Action Plan (draft and final) |
| | June 1998 | Site Closure by TNRCC |

# TECHNOLOGY SYSTEM PERFORMANCE

## CLEANUP GOALS/STANDARDS

The groundwater beneath the site is designated as Category II (TDS concentration of affected groundwater is less than 3,000 mg/L and no beneficial use is documented within 0.5 mile of the site, or the TDS is between 3,000 and 10,000 mg/L and beneficial use is documented within 0.5 mile of the site). The TNRCC (1994) Plan A target concentrations for Category II aquifers, and the TNRCC (1997) target concentrations for construction worker exposure are the cleanup goals for affected groundwater. Only the Plan A concentration for benzene of 0.0294 mg/L was exceeded.

Maximum-detected concentrations of BTEX in soil gas were compared to the chemical-specific OSHA 8-hour time-weighted average permissible exposure limits (PELs), and there were no exceedences.

## PERFORMANCE DATA AND DATA ASSESSMENT

Results of previous groundwater sampling events indicate that the dissolved contaminant plume is not increasing in areal extent. Natural attenuation indicator parameters exhibit trends associated with a plume which is being naturally degraded. Because the source is mostly removed (prior excavation of contaminated soils), biodegradation will continue to decrease the concentrations of dissolved contaminants. Assimilative capacity calculations suggest that the shallow groundwater has the biological capacity to attenuate the existing contamination. BIOSCREEN modeling results indicate that the dissolved plume will not migrate off-site at levels above TNRCC criteria, and benzene concentrations should decrease below the cleanup goal within 10 years.

### PERFORMANCE DATA QUALITY

An electronic Level III validation was performed on the February 1998 analytical results obtained from the fixed-base laboratories. Analytical results associated with non-compliant QC criteria were qualified appropriately.

## COST OF THE TECHNOLOGY SYSTEM

### PROCUREMENT PROCESS

Procurement involved selection of an analytical subcontractor. Bids were obtained from three qualified analytical laboratories, and the selected firm was Quanterra in Wheat Ridge, Colorado.

### COST DATA

(Identify organization that provided cost data and whether cost data are actual or estimated costs)

| Item | Cost ($ Year Basis) | Actual or Estimated (A or E) |
|---|---|---|
| Capital (specify cost/activity) | NA | NA |
| Operation and maintenance (specify cost/activity) | NA | NA |
| Other (specify) | NA | NA |

## REGULATORY/INSTITUTIONAL ISSUES

Identify the approvals, licenses, and permits required to operate the technology at the site.

NA

## TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Identify technology applicability, competing technologies, and technology maturity; may also discuss commercialization and intellectual property issues.

Remediation by natural attenuation (RNA) is applicable for all petroleum-hydrocarbon contaminated sites. RNA is advantageous for the following reasons:

- Contaminants can be transformed to innocuous byproducts (e.g., carbon dioxide or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally no more effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA can be less costly than conventional, engineered remedial technologies.

A potential disadvantage of RNA is that, in some cases, natural attenuation rates are too slow to make RNA a practical remedial alternative.

# OBSERVATIONS AND LESSONS LEARNED

## COST OBSERVATIONS AND LESSONS LEARNED

Provide observations and lessons learned related to cost of the application.

No costs will be incurred due to regulatory site closure.

## PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

The following conclusions were drawn from the risk-based assessment of the site:

Given the low potential for current or future exposure to site contaminants, the historical groundwater data which indicates a contaminant plume that is not increasing in areal extent, and the strong geochemical evidence that natural attenuation is occurring at the site, Former Building 2093 is a candidate for immediate closure according to TNRCC guidance. Given the fact that dissolved benzene concentrations in groundwater remain above TNRCC Plan A Category II criteria near the source area, Kelly AFB proposes to restrict use of the shallow groundwater at the site.

## OTHER OBSERVATIONS AND LESSONS LEARNED

The risk-based corrective action program administered by the PST Division of the TNRCC allows for rapid site closure if the groundwater contaminant plume is stable or declining in magnitude and/or size, the beneficial impacts of natural attenuation can be documented, and the potential for current or future expousre of receptors to site contamination is low. The risk-based corrective action process performed for this site can be used to achieve cost-effective site closure at other relatively low-risk fuel-contaminated sites.

**List of references used in preparation of the cost and performance report.**

# REFERENCES


Newell, C.J., Mcleod, R.K., and Gonzales, J.R. 1996. *Bioscreen Natural Attenuation Design Support System User's Manual*, Version 1.3. Prepared for the Environmental Services Office, Air Force Center for Environmental Excellence (AFCEE) by Groundwater Services, Inc. June.

TNRCC. 1997c. Target Concentrations for Construction Worker Exposures. Facsimile from Vicki Montgomery at TNRCC Petroleum Storage Tank Division. Extracted from the March 6, 1997 TNRCC memorandum Clarifications and Amendments for Implementation of RG-36. July 24.

TNRCC. 1994. Risk-Based Corrective Action for Leaking Underground Storage Tank Sites. RG-36. January.

# ACKNOWLEDGMENTS

This case study report was prepared by Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, 303-831-8100. The report was prepared for Jim Gonzales at AFCEE/ERT under AETC Contract No. F41689-96-D-0710, Delivery Order 5015.

# APPENDIX C

# SUMMARY DATA TABLE

## SUMMARY DATA TABLE
### STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | Final Report Date | Current or Prior Engineered Remediation[b/] | Soil COPCs[a/] | | |
|---|---|---|---|---|---|---|
| | | | | Benzene | Ethylbenzene | Xylenes |
| Eglin AFB, FL | Seventh Street Service Station | March-1999 | GE, BV | --[c/] | X[d/] | X |
| Eglin AFB, FL | Military Gas Station | March-1999 | AS, SVE | -- | -- | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | July-1998 | Soil Excavation | X | -- | -- |
| Randolph AFB, TX | BX Service Station | May-1998 | NA[e/] | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | April-1999 | DDC | -- | -- | -- |
| Tyndall AFB, FL | BX Service Station | August-1999 | NA | X | -- | -- |
| Tyndall AFB, FL | FT-16 | August-1999 | NA | -- | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | July-1999 | PR | -- | -- | -- |
| Pope AFB, NC | ST-08 | September-1999 | BV | -- | -- | -- |

| Air Force Facility | Site | Maximum Soil COPC Concentration (mg/kg)[f/] | | |
|---|---|---|---|---|
| | | Benzene | Ethylbenzene | Xylenes |
| Eglin AFB, FL | Seventh Street Service Station | -- | 710 | 1400 |
| Eglin AFB, FL | Military Gas Station | -- | -- | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | 2.7 | -- | -- |
| Randolph AFB, TX | BX Service Station | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- |
| Tyndall AFB, FL | BX Service Station | <2.4 | -- | -- |
| Tyndall AFB, FL | FT-16 | -- | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | -- | -- |

[a/] COPC = Chemical of potential concern.

[b/] GE = Groundwater extraction, BV = Bioventing, AS = Air Sparging, SVE = Soil vapor extraction, DDC = Density-driven convection, PR = Product recovery.

[c/] "--" indicates that the contaminant was not a COPC.

[d/] "X" = The contaminant was a COPC.

[e/] NA = Not analyzed.

[f/] mg/kg = Milligrams per kilogram.

## SUMMARY DATA TABLE
### STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | Groundwater COPCs[a/] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Benzene | Toluene | Ethylbenzene | Xylenes | Lead | Total Lead |
| Eglin AFB, FL | Seventh Street Service Station | X[b/] | X | X | X | --[c/] | X |
| Eglin AFB, FL | Military Gas Station | -- | -- | X | X | X | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | X | -- | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | X | -- | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- | -- | -- | X |
| Tyndall AFB, FL | BX Service Station | X | X | X | X | X | -- |
| Tyndall AFB, FL | FT-16 | X | -- | X | X | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | -- | -- | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | -- | -- | -- | -- | -- |

| Air Force Facility | Site | Groundwater COPCs (Continued) | | | | |
|---|---|---|---|---|---|---|
| | | TRPH[d/] | Naphthalene | MTBE[e/] | Benzo(b)fluoranthene | Benzo(k)fluoranthene |
| Eglin AFB, FL | Seventh Street Service Station | X | X | -- | -- | -- |
| Eglin AFB, FL | Military Gas Station | -- | X | -- | -- | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | -- | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | -- | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- | -- | -- |
| Tyndall AFB, FL | BX Service Station | X | X | X | -- | -- |
| Tyndall AFB, FL | FT-16 | X | -- | -- | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | -- | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | -- | -- | X | X |

[a/] COPC = Chemical of potential concern.

[b/] "X" = The contaminant was a COPC.

[c/] "--" indicates that the contaminant was not a COPC.

[d/] TRPH = Total recoverable petroleum hydrocarbons.

[e/] MTBE = Methyl tertiary butyl ether.

## SUMMARY DATA TABLE
### STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | Maximum Groundwater COPC[a/] Concentration (μg/L)[b/] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Benzene | Toluene | Ethylbenzene | Xylenes | Lead | Total Lead | TRPH[c/] | Naphthalene |
| Eglin AFB, FL | Seventh Street Service Station | 86 | 11000 | 1600 | 13000 | -- | 19 | 38000 | 510 |
| Eglin AFB, FL | Military Gas Station | --[d/] | -- | 76 | 400 | 19 | -- | -- | 40 |
| Kelly AFB, TX | Former Building 2093 Gas Station | 2200 | -- | -- | -- | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | 7.1 | -- | -- | -- | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- | -- | -- | 21 | -- | -- |
| Tyndall AFB, FL | BX Service Station | 3400 | 5000 | 3100 | 16000 | 62 | -- | 41000 | 320 |
| Tyndall AFB, FL | FT-16 | 71 | -- | 44 | 39 | -- | -- | 7.1 | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | -- | -- | -- | -- | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | -- | -- | -- | -- | -- | -- | -- |

| Air Force Facility | Site | Maximum Groundwater COPC Concentration (μg/L) Continued | | | Soil Gas COPCs | | | Maximum Soil Gas COPC Concentration (ppmv)[e/] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MTBE[f/] | Benzo(b)fluoranthene | Benzo(k)fluoranthene | Benzene | Toluene | Xylenes | Benzene | Toluene | Xylenes |
| Eglin AFB, FL | Seventh Street Service Station | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Eglin AFB, FL | Military Gas Station | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Tyndall AFB, FL | BX Service Station | 1300 | -- | -- | X[g/] | -- | -- | 24 | -- | -- |
| Tyndall AFB, FL | FT-16 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | -- | -- | X | X | X | 260 | 59 | 110 |
| Pope AFB, NC | ST-08 | -- | 1 | 0.7 | -- | -- | -- | -- | -- | -- |

[a/] COPC = Chemical of potential concern.

[b/] μg/L = Micrograms per liter.

[c/] TRPH = Total recoverable petroleum hydrocarbons.

[d/] "--" indicates that the contaminant was not a COPC.

[e/] ppmv = parts per million by volume.

[f/] MTBE = Methyl tertiary butyl ether.

[g/] "X" = The contaminant was a COPC.

**SUMMARY DATA TABLE**
**STREAMLINED RBCA SITE CLOSURE PROJECT**

| Air Force Facility | Site | Historical Reductions in Contaminant Concentrations | |
|---|---|---|---|
| | | Soil | Groundwater |
| Eglin AFB, FL | Seventh Street Service Station | Substantial reductions in vadose zone since 1992 | Decreasing levels since 1994 |
| Eglin AFB, FL | Military Gas Station | Substantial reductions in vadose zone since 1994 | Decreasing levels since 1992 |
| Kelly AFB, TX | Former Building 2093 Gas Station | NA[a/] | Oscillating up and down |
| Randolph AFB, TX | BX Service Station | NA | Oscillating up and down |
| Keesler AFB, MS | BX Service Station | Substantial reductions since 1992 | Oscillating up and down |
| Tyndall AFB, FL | BX Service Station | Overall decrease since 1995 | Variable, but stable to decreasing from 1997 to 1998 |
| Tyndall AFB, FL | FT-16 | Overall decrease since 1995 | Consistent decrease since 1995 |
| Seymour Johnson AFB, NC | Building 4522 | Substantial reduction since 1996 | Decrease since 1996 |
| Pope AFB, NC | ST-08 | Substantial reduction since 1995 | Decrease since 1997 |

| Air Force Facility | Site | Calculated Biodegradation rate ($day^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | BTEX[b/] | Benzene | Toluene | Ethylbenzene | Xylenes | Naphthalene |
| Eglin AFB, FL | Seventh Street Service Station | 0.006-0.01 | --[c/] | -- | -- | -- | -- |
| Eglin AFB, FL | Military Gas Station | -- | -- | -- | 0.001 | -- | 0.0007 |
| Kelly AFB, TX | Former Building 2093 Gas Station | -- | 0.002 | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | -- | 0.003-0.004 | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | -- | -- | -- | -- | -- | -- |
| Tyndall AFB, FL | BX Service Station | -- | 0.0067 | 0.017 | 0.0059 | 0.0073 | -- |
| Tyndall AFB, FL | FT-16 | -- | 0.0052 | 0.0027 | 0.006 | 0.0033 | -- |
| Seymour Johnson AFB, NC | Building 4522 | 0.0026 | 0.0049 | -- | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | -- | -- | -- | -- | -- |

[a/] NA = Data not available.

[b/] BTEX = Benzene, toluene, ethylbenzene, and xylenes.

[c/] "--" indicates that a biodegradation rate was not calculated.

## SUMMARY DATA TABLE
### STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | Groundwater Assimilative Capacity (mg/L)[a/] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | BTEX[b/] | Benzene | Toluene | Ethylbenzene | Xylenes | Naphthalene | MTBE[c/] | Benzo(b)fluoranthene | Benzo(k)fluoranthene |
| Eglin AFB, FL | Seventh Street Service Station | --[d/] | 13.1 | 12.9 | 12.7 | 12.7 | 13.4 | -- | -- | -- |
| Eglin AFB, FL | Military Gas Station | -- | -- | -- | 12.6 | 12.6 | 13.2 | -- | -- | -- |
| Kelly AFB, TX | Former Building 2093 Gas Station | -- | 12.5 | -- | -- | -- | -- | -- | -- | -- |
| Randolph AFB, TX | BX Service Station | -- | 13-20.4 | -- | -- | -- | -- | -- | -- | -- |
| Keesler AFB, MS | BX Service Station | 11.2 | -- | -- | -- | -- | -- | | -- | -- |
| Tyndall AFB, FL | BX Service Station | -- | 16.6 | 16.3 | 16.1 | 16.1 | 16.7 | 18.5 | -- | -- |
| Tyndall AFB, FL | FT-16 | -- | 3.96 | -- | 3.85 | 3.85 | -- | -- | -- | -- |
| Seymour Johnson AFB, NC | Building 4522 | -- | 3.27 | 3.22 | 3.18 | 3.18 | 2.97 | -- | -- | -- |
| Pope AFB, NC | ST-08 | -- | 9.49 | 9.32 | 9.22 | 9.22 | 9.6 | -- | 9.86 | 9.86 |

| Air Force Facility | Site | Number of Plumes | Estimated Plume Stability Based on Groundwater Quality | BIOSCREEN Modeling Results - Simulated Migration Relative to Measured Plume | | |
|---|---|---|---|---|---|---|
| | | | | Compound Simulated | 1st Order Routine | Instantaneous Reaction Routine |
| Eglin AFB, FL | Seventh Street Service Station | 1 | Hydraulically Controlled | Xylenes | Additional 130 ft | Additional 690 ft |
| Eglin AFB, FL | Military Gas Station | 1 | Receding | NA[e/] | NA | NA |
| Kelly AFB, TX | Former Building 2093 Gas Station | 1 | Stable | Benzene | Additional 150 ft | NA |
| Randolph AFB, TX | BX Service Station | 2 | Stable(1), ND[f/] (2) | Benzene | Receding (1), ND (2) | Additional 80-180 ft (1), ND |
| Keesler AFB, MS | BX Service Station | 1 | Stable | NA | NA | NA |
| Tyndall AFB, FL | BX Service Station | 2 | Stable (1), Receding (2) | Benzene + Xylenes | NA | Both receding |
| Tyndall AFB, FL | FT-16 | 1 | Stable to Receding | Benzene | ND | NA |
| Seymour Johnson AFB, NC | Building 4522 | 1 | Expanding | Benzene | Additional 230 ft | NA |
| Pope AFB, NC | ST-08 | 1 | ND | Benzene | NA | Additional 150 ft |

[a/] mg/L = Milligrams per liter.

[b/] BTEX = Benzene, toluene, ethylbenzene, and xylenes.

[c/] MTBE = Methyl tertiary butyl ether.

[d/] "--" indicates that an assimilative capacity was not calculated.

[e/] NA = Not applicable.

[f/] ND = Not determined.

# SUMMARY DATA TABLE
## STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | BIOSCREEN Modeling Results (Continued) | | | |
|---|---|---|---|---|---|
| | | Simulated Effects of 80% Source Removal | | Simulated Persistence of COPC[a] Above Tier 1 RBSL[b] | |
| | | Predicted Migration | | | |
| | | 1st Order Routine | Instantaneous Reaction Routine | 1st Order Routine | Instantaneous Reaction Routine |
| Eglin AFB, FL | Seventh Street Service Station | Additional 130 ft | Additional 340 ft | >1000 µg/L for >400 yr | 150 yr |
| Eglin AFB, FL | Military Gas Station | NA[c] | NA | NA | NA |
| Kelly AFB, TX | Former Building 2093 Gas Station | NA | NA | 10 yr | 5 yr |
| Randolph AFB, TX | BX Service Station | NA | NA | >13 yr | 8 yr |
| Keesler AFB, MS | BX Service Station | NA | NA | NA | NA |
| Tyndall AFB, FL | BX Service Station | NA | Both Receding Faster | NA | 20-69 yr |
| Tyndall AFB, FL | FT-16 | NA | NA | 7 yr | 1 yr |
| Seymour Johnson AFB, NC | Building 4522 | NA | NA | ND [d] | ND |
| Pope AFB, NC | ST-08 | NA | NA | ND | ND |

| Air Force Facility | Site | Tier 2 Chemicals of Concern (COCs)[e] | | | |
|---|---|---|---|---|---|
| | | Groundwater COCs | Soil Gas COCs | Soil COCs | Surface Water COCs |
| Eglin AFB, FL | Seventh Street Service Station | None | None | None | NA |
| Eglin AFB, FL | Military Gas Station | None | None | None | NA |
| Kelly AFB, TX | Former Building 2093 Gas Station | None | None | None | NA |
| Randolph AFB, TX | BX Service Station | None | None | None | NA |
| Keesler AFB, MS | BX Service Station | None | None | None | NA |
| Tyndall AFB, FL | BX Service Station | Benzene | None | None | NA |
| Tyndall AFB, FL | FT-16 | None | None | None | NA |
| Seymour Johnson AFB, NC | Building 4522 | None | Benzene | None | NA |
| Pope AFB, NC | ST-08 | None | None | None | None |

[a] COPC = Chemical of potential concern.

[b] RBSL = Risk based screening level.

[c] NA = Not applicable.

[d] ND = Not determined.

[e] COC = Chemical of concern with concentration exceeding Tier 2 site-specific target level.

## SUMMARY DATA TABLE
### STREAMLINED RBCA SITE CLOSURE PROJECT

| Air Force Facility | Site | Risk Assessment Results: Potential, Current or Future Risk to Receptors? | emediation Alternatives Considered | Number of LTM[b/] Wells Proposed | Recommended LTM Duration (yr) | Recommended LTM Frequency |
|---|---|---|---|---|---|---|
| Eglin AFB, FL | Seventh Street Service Station | No | MNA + IC, BS + SVE, GE + SVE | 6 | 30 | Semiannual for 5 yrs, then biennial for 25 yrs |
| Eglin AFB, FL | Military Gas Station | No | MNA + IC | 4 | 9 | Annual for 3 yrs, then biennial for 6 yrs |
| Kelly AFB, TX | Former Building 2093 Gas Station | No | MNA + IC | 0 | 0 | NA |
| Randolph AFB, TX | BX Service Station | No | MNA + IC + BV | 11 | 2 | Semiannual |
| Keesler AFB, MS | BX Service Station | No | MNA + IC | 9 | 5 | Quarterly for 1 yr, then annual for 4 yrs. |
| Tyndall AFB, FL | BX Service Station | Yes- Future onsite intrusive workers | MNA + IC, MNA + IC + BS + SVE | 8 | 3 | Annual |
| Tyndall AFB, FL | FT-16 | No | MNA | 5 | 3 | Annual |
| Seymour Johnson AFB, NC | Building 4522 | Yes- Future indoor receptors from inhalation of benzene | MNA + IC + PR | 0 | 0 | NA |
| Pope AFB, NC | ST-08 | No | NA[c/] | ND | NA | NA |

| Air Force Facility | Site | Remedial Alternative Costs | Recommendation |
|---|---|---|---|
| Eglin AFB, FL | Seventh Street Service Station | $270,000, $490,000, $540,000 | BS+SVE or GE+SVE |
| Eglin AFB, FL | Military Gas Station | ND[d/] | Closure contingent on LTM |
| Kelly AFB, TX | Former Building 2093 Gas Station | ND | Closure |
| Randolph AFB, TX | BX Service Station | ND | Closure contingent on LTM |
| Keesler AFB, MS | BX Service Station | ND | Closure contingent on LTM |
| Tyndall AFB, FL | BX Service Station | $214,000, $505,000 | MNA to SSTLs then inactive but managed status |
| Tyndall AFB, FL | FT-16 | ND | Closure contingent on LTM |
| Seymour Johnson AFB, NC | Building 4522 | ND | Continue product recovery, then close based on low risk |
| Pope AFB, NC | ST-08 | ND | ND |

[a/] MNA = Monitored natural attenuation, IC = Institutional controls, BS = Biosparging, GE = Groundwater extraction, BV = Bioventing, SVE = Soil vapor extraction, DDC = Density-driven convection, PR = Product recovery.

[b/] LTM = Long-term monitoring

[c/] NA = Not applicable.

[d/] ND = Not determined.